VHF/UHF Propagation

Long-Distance VHF Ducting Opportunities from Australia

*Emil Pocock W3EP**

Every summer for the past two decades, dozens of 4000 km contacts have been completed between Hawaii and California on 144 through 5760 MHz. This is well beyond the normal distance for VHF and UHF communication, yet even low-powered FM stations have made the grade. These contacts are made possible by a reliable tropospheric duct, a kind of natural waveguide in the lower atmosphere, that forms predictably each year between the Hawaiian Islands and the West Coast of North America. Although this is perhaps the most famous of the oceanic ducts, similar conditions exist over all the world's sub-tropical oceans, including those adjacent to Australia. It seems likely that future records will not be made from California or Hawaii, but rather over the Indian or Atlantic oceans.

Australian-born Ross Hull, writing in a 1935 *QST* article, provided one of the first explanations of how conditions in the troposphere, the lowest weather-producing region of the atmosphere, could support long-distance VHF radio propagation. Experiences over the following decade suggested that the potential for transoceanic ducting might be quite extensive. Military radar operators in the Indian and Pacific oceans observed echoes from 2500 km and farther using 144-MHz equipment during World War II. In October 1945, W5GSG/KH6 heard a 127 MHz air controller on Christmas Island, 1600 km from Hawaii. Other long-distance VHF communications were also reported in amateur publications during the 1940s (Ref 1).

Professionals began studying this phenomenon over the Atlantic and Pacific oceans during the 1950s using airborne instruments and VHF ground stations. The resulting scientific articles provided the first descriptions of the trade-wind duct, as these studies called the unusual upper-air conditions that supported long-distance VHF communication over the semitropical oceans (Ref 2). By the mid-1950s, John Chambers KH6UK and Ralph Thomas W6NLZ were planning to span the even longer path between Hawaii and California on 144 MHz using a tropospheric duct they were confident existed over the eastern Pacific.

The Historic Hawaii-California Path

On 8 July 1957, after more than a year of tests, KH6UK and W6NLZ finally made a historic 144 MHz contact. The pair repeated the feat two years later on 220 MHz, but few others seemed interested in duplicating this pioneering work. A breakthrough came during July 1973, when dozens of two-metre operators unexpectedly made several hundred QSOs between Hawaii and California, primarily through a Hawaiian FM repeater at 2440 metres elevation (Ref 3). In the years that followed, the reliable Hawaiian duct has provided countless contacts between the islands and California. Paul Lieb KH6HME and Louis Anciaux WB6NMT completed the first 432 MHz contact over this path in July 1979, and the most optimistic operators assumed that making it on even higher bands was just a matter of time. Indeed it was. By August 1995, Hawaii had been linked to the American mainland as high as 5760 MHz (see Table 1).

North American operators now look forward to several days' worth of long-distance VHF and UHF ducting conditions to Hawaii every summer. The most productive months are July and August, but the duct has been observed often enough as late as December. It rarely appears during the first half of the year (Ref 4). This predictable cycle of duct formation corresponds closely to the annual movement of a semi-permanent region of high atmospheric pressure in the eastern Pacific, known as the Hawaiian High.

During July and August, the centre of the Hawaiian High is usually situated close to 40 degrees north latitude. Ducting paths commonly form on the equatorial side of the centre of high pressure, as shown in Figure 1.

During September and October, the high weakens as it migrates southward. It lies at its most southerly extent around 30 degrees north latitude in January. It then begins a northward migration during March and April to complete an

Table 1
Record Tropo Contacts

Band (MHz)	*Date*	*Stations*	*Distance (km)*
144	1995 June 30	KH6HME—W7FI	4333
220	1989 July 15	KH6HME—XE2/N6XQ	4142
432	1989 July 15	KH6HME—XE2/N6XQ	4142
902	1994 July 13	KH6HME—N6XQ	4061
1296	1989 July 15	KH6HME— XE2/N6XQ	4142
2304	1994 July 14	KH6HME—N6CA	3973
3456	1991 July 28	KH6HME—N6CA	3973
5760	1991 July 29	KH6HME—N6CA	3973
10 GHz	1994 Dec 30	VK6KZ—VK5NY	1991

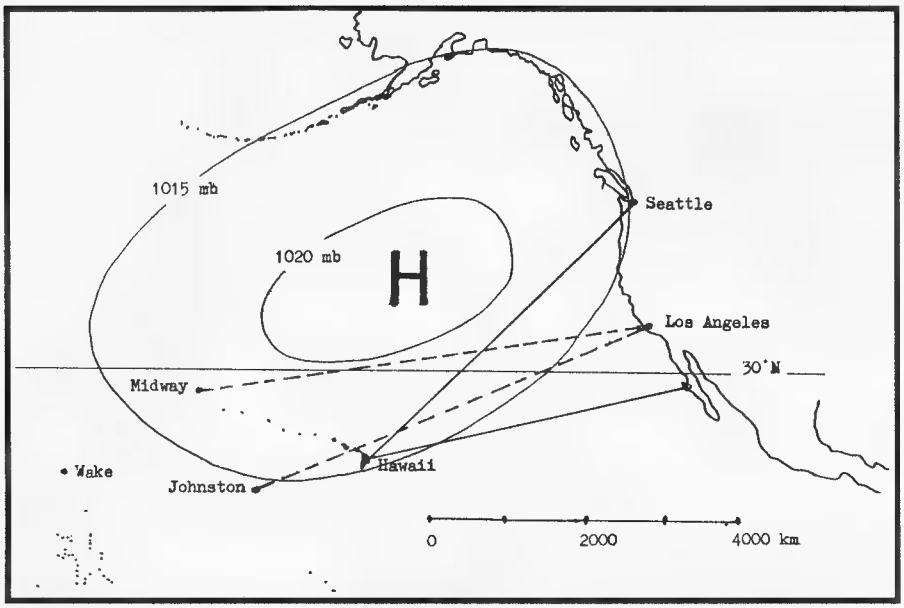

Figure 1 – Mean location of the Hawaiian High and sea-level pressure (mb) during July and August. Solid lines indicate observed 144 MHz ducting paths. Dotted lines show possible 144 MHz ducting paths.

annual cycle. This process is duplicated in other subtropical regions, most notably in the southern hemisphere over the Indian Ocean. The reasons why large high-pressure regions migrate during the course of the year and the mechanism by which they create stable long-distance tropospheric ducts are related phenomena.

Ducts, Temperature Inversions, and Subsidence

Temperature inversions form under several different weather conditions, but they are most commonly associated with subsidence. When air is forced downward through the troposphere, it is compressed by the increasing atmospheric pressure. Because the temperature of a volume of compressed air rises, subsiding air is warmed. This warming is a source of upper-air temperature inversions and, ultimately, of ducting conditions. Subsiding air is usually much drier than the surrounding air as well, because it originated as much cooler air higher in the atmosphere. Cool air can hold very little moisture and none is added as it subsides. Thus the air in temperature inversions caused by subsidence is both warmer and drier than the air below, ideal for ducting.

Large-scale subsidence is one of the characteristics of atmospheric high-pressure regions, or anticyclones. The air within warm-weather anticyclones descends through the atmosphere from 10,000 metres and higher. The descending air is compressed, heated, and dried. Several layers of distinct temperature inversions may appear from several thousand metres altitude to near the Earth's surface, although the lowest inversion is usually the most useful for ducting. The weather directly under high-pressure is generally clear, warm, and dry, with light and variable breezes. The descending air eventually flows out over the surface of the Earth, making anticyclones inherently expanding systems. Coriolis and centrifugal forces derived from the Earth's rotation, along with frictional forces along the Earth's surface, turn this flow in a counter-clockwise direction in the southern hemisphere, creating a steady breeze around the outer portions of the anticyclone (Ref 5).

Anticyclone Formation and Global Atmospheric Circulation

Large semi-permanent regions of high pressure, such as the Hawaiian High and the similar Réunion High over the Indian Ocean, are sustained by global air circulation patterns. The Earth's surface is generally warmest over the equatorial regions. Surface heating causes massive air currents to rise into the troposphere, creating a belt of low pressure near the equator. This rising equatorial air spreads north and south, gradually cools, and sinks around 30 degrees from the equator, forming two globe-encircling subtropical anticyclone belts. It is here that great transoceanic ducts commonly form. These generally calm regions are also known as the horse latitudes, so named because sailors on becalmed sailing ships were sometimes forced to throw horses and cattle overboard for lack of feed and water. Over much of the

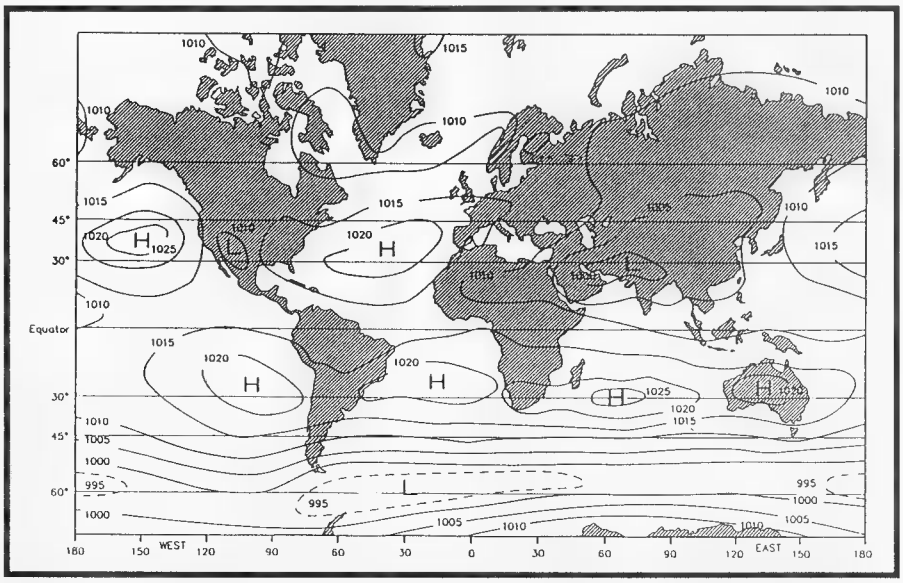

Figure 2 – Mean sea-level atmospheric pressure (mb) over the Earth during July. Adopted from P Tchernia, "Descriptive Regional Oceanography" (Oxford: Pergamon, 1980), plate 3.

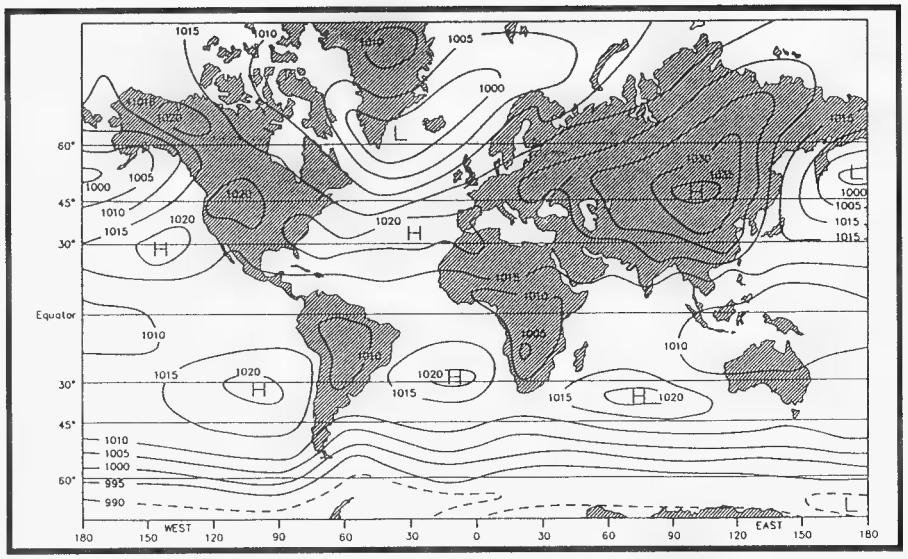

Figure 3 – Mean sea-level pressure (mb) over the Earth during January. Adopted from Tchernia, plate 2.

land area at the same latitudes, subsiding warm, dry, air creates the world's great deserts, such as those of interior Australia.

The upper-atmospheric circulation and associated surface features, including the sub-tropical anti-cyclones, migrate north and south due to the Earth's variable tilt in relation to the sun. The Earth's angle to the sun varies over a 47 degree range during the course of a year. The position of the upper-air circulation cells shift accordingly and pull the sub-tropical anti-cyclones over a 10 to 15 degree range annually. The mean pressure, total area, and northerly extent of the anti-cyclone belts are generally greatest in July (Ref 6). Compare Figures 2 and 3.

Although the model of atmospheric circulation suggests high pressure would appear as a continuous belt at about 30 degrees north and south latitude, the belt is actually broken into separate anti-cyclonic systems. Surface heating over the continental land masses partially counters the effects of subsidence, leaving the most prominent semi-permanent high-pressure regions over the oceans. Just two semi-permanent anticyclones form in the northern hemisphere, the Pacific Hawaiian High and the Atlantic Bermuda-Azores High. Three separate highs appear in the southern hemisphere over the Pacific, Atlantic, and Indian oceans, in addition to the exceptional continental high over Australia in winter. The Réunion High over the Indian Ocean is most notable. Each has the potential to support long-distance ducting conditions at VHF and higher.

Australia and the Réunion High

The most spectacular long-distance tropospheric ducting contacts in Australia so far have been in the 2000 km range across the Great Australian Bight. The recent 10 GHz world record of 1911 km, made by Wally Howse VK6KZ and Robert Bowman VK5NY on 30 December 1994, attests to the generally favourable ducting conditions that are present over the area in summer. Nevertheless, the future for this path is limited. Distances could be extended a few hundred more kilometres from Tasmania, but that would just about exhaust the potential of trans-Bight paths. In contrast, the possibilities from Australia over the western Pacific and the Indian oceans are much greater.

VHF contacts via tropospheric ducting have been reported occasionally from the east coast to New Zealand and other nearby islands, but these paths have not approached the distances achieved by the Americans. This could be explained in part by Figures 2 and 3, which suggest that the belt of semi-tropical high pressure is generally weak between Australia and the mid-Pacific. Thus the potential for world record-breaking paths in the western Pacific appear less likely than elsewhere. Even so, ducting paths might be possible as far as Tonga (3300 km) or even further. An entirely different situation exists off the west coast, where the Réunion High dominates the southern Indian Ocean and might offer some very exciting possibilities.

The Réunion High sprawls between Australia and South Africa, as shown in Figure 4. It appears to reach its greatest strength in July and August, although it is not clear if winter is the most favourable time for duct formation. In any event, the strongest ducts would likely form to the north of the high pressure centre. Reliable VHF paths probably occur between South Africa and various mid-Indian Ocean islands, such as Réunion, Mauritius, and Rodrigues. The distance from Port Elizabeth to Rodrigues is about 4100 km, or about the same as the current world records made between Hawaii and North America. Longer contacts, such as Réunion to north-western Australia (about 9950 km) or entirely across the Indian Ocean (over 11,000 km) appear fantastic, yet they may be worth attempting in a series of progressive trials from the South African side.

The main problem from the Australian end is the absence of islands at intermediate distances to the west. Cocos is probably too far north and Amsterdam Island too far south to be within a duct formed under the Réunion High. The closest islands in favourable locations are those in the Rodrigues group, 5150 km from the nearest point on the western Australian coast. One problem is that it is unlikely there are any permanent VHF operators on Rodrigues to participate in trans-oceanic tests. Maritime mobile operations or expeditions, perhaps attached to low-band DX groups, might provide the needed opportunities to test the potential of ducting over the Indian Ocean.

Possibilities in Other Parts of the World

VHF contacts sustained by the Réunion High have the potential for yielding the ultimate tropospheric ducting distance records, but practical difficulties of establishing VHF operations in favourable locations may delay realising these goals. It does not

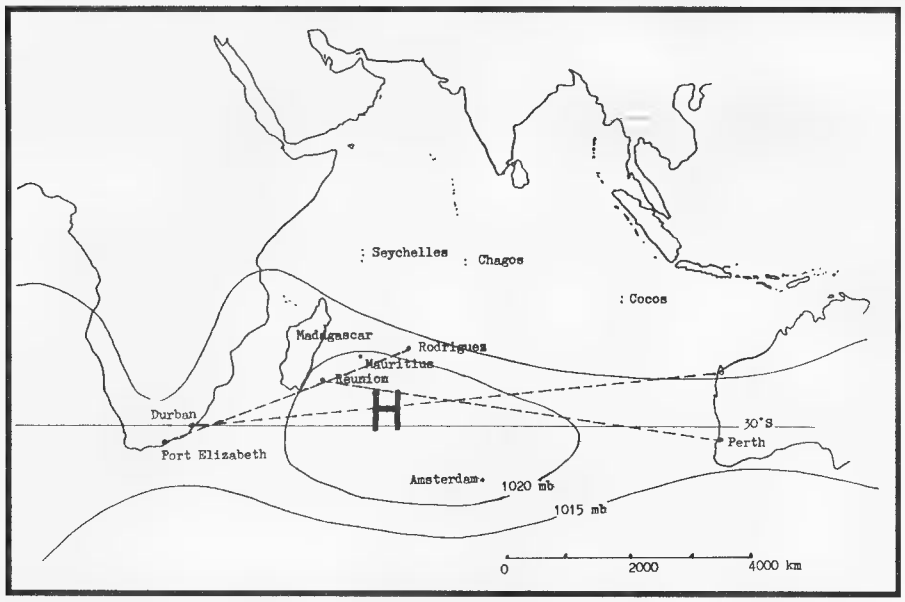

Figure 4 – Mean location of the Réunion High and sea-level pressure (mb) during August and September. Dotted lines suggest possible 144 MHz ducting paths.

seem likely that the distances over the eastern Pacific will be extended dramatically. The North American side is limited by a nearly continuous range of coastal mountains, which rise higher than the normal elevation of the duct. The western end could possibly be stretched to the outer Hawaiian islands as far as Midway (5475 km from Los Angeles) or possibly to Johnston Island (5600 km) if there were VHF operators at these locations. A California to Wake Island contact (7375 km) appears to be a remote possibility.

Similar conditions over the north Atlantic Ocean, sustained by the Bermuda-Azores High, may yield record-breaking results much sooner. The most likely transatlantic paths lie between the Caribbean and the southern United States on the western side and southern Europe and North Africa to the east. These end points are generally well populated with serious VHF stations and preparations are already under way to test the possibilities. The distances involved are in the 6000 to 7000 km range, much further than those achieved in the eastern Pacific, but within practical reach. The announcement of the Brendan Trophies for the first 144-MHz transatlantic contact using terrestrial means of propagation may accelerate the search for a tropo-ducting path across the Atlantic (Ref 7).

No doubt avid VHF operators will be pushing toward the limits in the eastern Pacific and Atlantic oceans in the coming years, but there is no reason why distance records have to remain in the northern hemisphere. Although VHF activity levels may be lower in the Indian Ocean region than elsewhere in the world, the regions adjacent to Australian coasts may have the highest potential for the ultimate tropospheric ducting records.

References

1. Ross A Hull, "Air-Mass Conditions and the Bending of Ultra-High Frequency Waves", QST (June 1935), 13-18, 74, 76. See also Ed Tilton, "World Above 50 Mc. [112 and 127-MHz Ducting in the Pacific]", QST (Jan 1946), 53; and Ed Tilton, "Commercials Steal Our Thunder – Airline Ops Work 1000 Miles on 130.7 Mc", QST (July 1948), 66.

2. D L Ringwalt and F C MacDonald, "Elevated Duct Propagation in the Tradewinds", IRE Transactions on Antennas and Propagation (July 1961), 377-83; and N W Guinard, J Ransone, D Randall, C Purves, and P Watkins, "Propagation Through an Elevated Duct: Tradewinds III," IEEE Transactions on Antennas and Propagation (July 1964), 479-90.

3. For details of these achievements, see Ed Tilton, "World Above 50 Mc [KH6UK – W6NLZ 144-MHz Contact]", QST (Sept 1957), 62-63; Ed Tilton, "World Above 50 Mc [KH6UK-W6NLZ 220-MHz Contact]", QST (Aug 1959), 68; and Bill Smith, "California-Hawaii Bridged on 146 and 432", QST (Sept 1973), 102; and Bill Smith, "Transpacific VHF Duct Propagation", QST (Nov 1973), 100-02.

4. These conclusions are based on the observations of Robert J Cooke, W6PJA, made between 1979 and 1986.

5. For more detailed discussion of duct formation, see Emil Pocock, "Transoceanic Ducting at VHF and Above", QST (March 1996), 41-46. For general background, see B R Bean and E J Dutton. Radio Meteorology (Washington: Government Printing Office, 1966).

6. P Tchernia, Descriptive Regional Oceanography (Oxford: Pergamon, 1980) and National Oceanic and Atmospheric Administration, National Climatic Data Center, Monthly Climatic Data for the World.

7. 'Announcing the Transatlantic 2 m Challenge: The Brendan Trophies", Radio Communications 71 (June 1995), 13; and Geoffrey H Grayer, "How to Win the Brendan Trophies", Radio Communications 71 (June 1995), 14-17.

**625 Exeter Road, Lebanon CT 06249, USA.*
E-mail: pocock@ecsuc.ctstateu.edu
Telephone: 860-642-7271 (1300-0300 UTC)

WIA News

Future of the Amateur Service Study

Details were given in July's *WIA News* of the International Amateur Radio Union's (IARU) moves to look into the future of the Amateur Service in preparation for consideration of the International Radio Regulations concerning amateur radio at the 1999 World Radio Conference (WRC-99).

WIA members wanting to read and comment on the IARU's paper on this issue are asked to contact their Division for a copy of the paper. All WIA Divisions have a copy of the paper, but only the larger Divisions have copying facilities. If a copy is difficult to obtain, contact the WIA Media Liaison Officer, VK2ZRH, at LMB 888, Woollahra 2025.